Switched-Capacitor Fifth-Order 1 Hz to 45 kHz Low-Pass Filter

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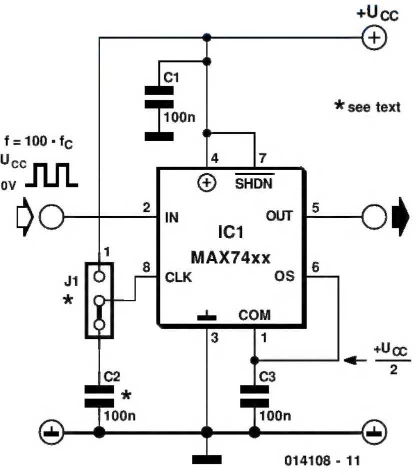
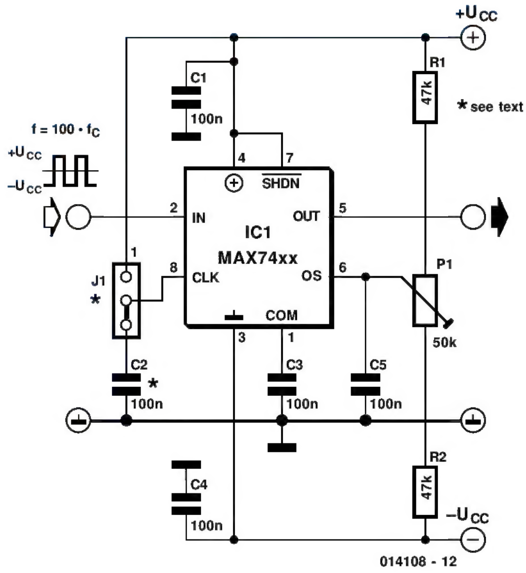




Low-pass LC-filters in the audio frequency range require huge ferrite-cored inductors. Active filters are also tricky to construct because of the tight tolerance required of the resistors and capacitors. Switched capacitor (SC) technology, however, allows small audio frequency low-pass filters with adjustable corner frequency to be constructed simply. The switching clock frequency used is 100 times higher than the desired corner frequency, so that any residual switching-frequency component at the output can be removed easily using an RC or LC low-pass combination.

Maxim (www.maxim-ic.com) has recently released eight new SC filter ICs with a current consumption of only 3 mA. Four different filter characteristics are available, and there are both 3 V and 5 V versions of the devices. The corner frequency can be continuously adjusted from 1 Hz to 45 kHz by suitable choice of clock frequency. **Table 1** gives an overview of the components and their chief characteristics.

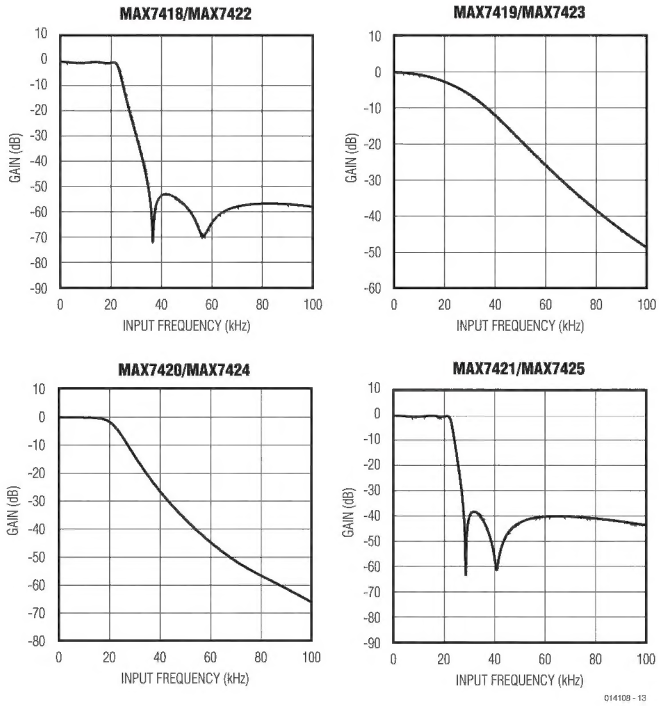
Figure 1 shows the frequency responses obtained with a clock frequency of 2.2 MHz, nominally giving a 22 kHz low-pass filter.

A second interesting possibility is stand-alone use without an external clock. A capacitor is connected to the CLK pin, which sets the frequency of a built-in oscillator circuit. This option is only suitable where the exact corner frequency is not important, since otherwise the capacitor must be adjusted to tune the corner frequency. The frequency of the internal oscillator also suffers from a slight drift with temperature.

The MAX74xx circuit can be powered either from a single 3 V or 5 V supply (according to the device) or from a symmetrical ±1.5 V (respectively ±2.5 V) supply. When using an external clock, note that a square wave with a duty cycle of 50 % ± 10 % is required, with a frequency 100 times the desired filter corner frequency and an amplitude appropriate for the supply voltage (see **Figure 2**).

The output DC offset can be calculated as follows:

Vout = (Vin – Vcom) + Vos



where Vcom is half the supply voltage (or 0 V when using a symmetrical supply). Vos is the offset compensation voltage, if any, fed into the OS pin. If the offset voltage need not be set, OS can be connected directly to COM. The formula thus tells us that if a single supply is used, a DC component equal to half the supply voltage is required. A reasonably low-impedance drive is required for the device, whereas the output should be connected to an impedance of at least 10 kΩ.

Table 1.

+3 V supply	+5 V supply	Filter frequency response	Characteristics
MAX 7422	MAX 7418	Elliptic filter, r = 1,6	53 dB stopband rejection
MAX 7423	MAX 7419	Bessel filter	linear phase
MAX 7424	MAX 7420	Butterworth filter	maximally flat passband
MAX 7425	MAX 7421	Elliptic filter, r = 1,25	37 dB stopband rejection

r = corner frequency / stopband lower frequency, i.e. steepness of cutoff in transition band

In stand-alone mode with a capacitor C connected to the CLK pin, the filter corner frequency depends on the capacitance as follows:

$$f_c = 0.01\ f_{osc} = 0.01\ k\Omega\ /\ C$$

Table 2.

+3 V supply	+5 V supply	k
MAX 7422	MAX 7418	$k = 87 * 10^3$
MAX 7425	MAX 7421	$k = 87 * 10^3$
MAX 7423	MAX 7419	$k = 110 * 10^3$
MAX 7424	MAX 7420	$k = 110 * 10^3$

Here C is in pF and f is in kHz. The appropriate value of k is given in **Table 2**.

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